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Sustainable Sports Nutrition – a Narrative Review of Evidence-Based Approaches Towards more Sustainable Diets for Athletes

Nachhaltige Sporternährung – ein narrativer Review über evidenzbasierte Ansätze für eine nachhaltigere Ernährung von Sportlern

REVIEW

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Summary

› **Introduction:** The intersection of sports and sustainability is increasingly significant, given the substantial environmental impact of sports activities. This includes constructing and maintaining sports facilities, athlete mobility, and waste generation at large events. Furthermore, athletes are often characterized by unsustainable dietary practices due to increased caloric intake, high protein intake, and dietary supplement consumption.

› **Purpose:** This narrative review aims to explore the role of athletes as frontrunners in promoting sustainable practices, particularly in their dietary choices, and to assess the potential environmental benefits of adopting more sustainable nutrition habits in sports.

› **Main outcomes:** The sports sector contributes significantly to greenhouse gas emissions, particularly through high energy consumption and waste production. Sustainable dietary changes, such as reducing consumption of animal products, can significantly lower the ecological footprint of athletes. Athletes may, as role models, influence public behavior towards more sustainable nutrition practices. Approaches to combine sustainable nutrition with key factors of sports nutrition regarding energy and nutrient intake could support health and performance of athletes. However, it might be challenging for athletes with poor food literacy.

› **Conclusion:** Promoting sustainable nutrition among athletes benefits the environment and may also support athletes in achieving their training goals due to well-balanced diets. Further research is needed to fully understand the long-term impacts of these dietary changes on athletic performance.

KEY WORDS:
Environmental Impact, Athletes' Diet, Responsibility, Plant-Based Protein, Performance Nutrition

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Introduction

In 2017, human-caused global warming was about 1°C above the pre-industrial era. Global warming >1.5°C leads to partially irreversible climatic changes, e.g., increased weather extremes such as heat waves, heavy rainfall, and rising sea levels. Global efforts must be made to reduce the extent of global warming and stay below the critical threshold (1). The United Nations identified 17 sustainable development goals (SDGs) for this purpose. The aim is to reduce the extent of global warming and promote sustainability. Almost all of the 17 SDGs include agricultural or nutritional aspects or issues of healthy and socio-economically fair and sustainable food supply (2). The industrial agricultural and food system is making a major contribution to the human-made climate change. According to the basic report "Planetary Health", published in The Lancet in 2015, global food production is responsible for 25 percent of greenhouse gas emissions and 70 percent of freshwater consumption and is associated with high subsequent costs for people and the environment (3). Artificial fertilization has also caused the nitrogen and phosphorus cycles to become unbalanced (3). It is estimated that ~40 percent of the world's land area is used for agriculture (3).

In addition to the serious consequences for the environment, current diets also cause health damage to a large part of the global population. There are two extremes: around 2 billion people worldwide have too much energy intake and suffer from overweight or obesity and their secondary diseases (e.g. metabolic syndrome). On the other hand, around 820 million people suffer from hunger or specific nutrient deficiencies. Without a significant change in food production and our diet, the United Nations' sustainability goals cannot be met (2).

Even if the contribution of sports nutrition seems marginal in this context, athletes who follow sustainable diets in publicity could make a contribution as role models to achieve the United Nations' sustainability goals. German organized sport, with around 27 million sports club members and a presumably even higher number of passive sports enthusiasts (i.e., people who follow major sporting ›

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events such as the German football league, the Olympic Games, European and World Championships), has an enormous reach and reaches people in many different phases of life. It is well documented that adolescents, in particular, can be influenced in their eating habits by modeling, by imitating the behavior of role models. The role model function is particularly strong when the people are popular and respected, their eating habits are clearly visible, and it is possible for the children to imitate the behavior. The eating habits of athletes as public figures, as well as the catering options and food marketing at major sporting events, are therefore ideal for modeling a more sustainable diet.

This narrative review aims to explore the role of athletes as frontrunners in promoting sustainable practices, particularly in their dietary choices, and to assess the potential environmental benefits of adopting more sustainable nutrition habits in sports.

Why Should Athletes Care For Sustainable Diets?

Athletes represent their home countries at international competitions formally only on a sporting level. However, athletes' impact outside the sporting competition should not be underestimated (4). Some scientists criticize that environmental activism among professional athletes remains low, although athletes as public figures could reach a wide audience when advocating a more sustainable lifestyle (4).

Athletes who take part in national and international competitions travel more frequently, which is associated with higher Greenhouse Gas (GhG) emissions. In addition, depending on the type of sport, the sport can be associated with high-energy costs and the use of other resources (e.g., snow, water, and ice sports). However, in elite and competitive sports, frequent traveling and/or energy-intensive equipment are essential. None of this is sustainable. It is, therefore, logical to compensate for this above-average consumption of consumer goods and energy as well as mobility compared to the general population by reducing the consumption of environmentally harmful resources in other areas of life, such as nutrition. Ruini et al. (2015) published the carbon, water, and ecological footprints for balanced diets with 2,025-2,140 kcal/day (5). The weekly impact was calculated as 11,781 gCO_{2eq} for vegan diets, 17,053 gCO_{2eq} for vegetarian diets, 25,294 gCO_{2eq} for flexitarian diets with five vegetarian days and meat consumption at the two remaining days and 48,894 gCO_{2eq} for a seven-day omnivore diet (5). It can be assumed that simply doubling food intake to account for athletic energy requirements of 4,000-4,500 kcal would approximately double the ecological impact of the given diet. However, reducing energy and food intake is, of course, no option for athletes towards a more sustainable diet, as energy and nutrient requirements need to be met to support both health and athletic performance. Thus, prudent and informed food choices are needed to reduce athletes' ecological footprint caused by their diets. This includes the reduction of foods with high GhG emissions, such as red meat, and replacing at least parts of these foods with nutrient-dense foods low or medium in GhG emissions. Athletes' diets should also include responsible decisions about dietary supplements regarding individual health, performance, and environmental impacts (6). Finally, reducing food waste, including food waste at sporting institutions and major events, reduction of packaging waste, and transportation of food (i.e., favoring locally produced food) are approaches that athletes can (more or less) easily adopt without any risks of not meeting the nutrient requirements.

Key Aspects of Sustainable Diets for Athletes

As part of environmental and climate developments, sustainable diets were first defined in 2010 as " diets with low environmental impacts which contribute to food and nutrition security and to healthy lives for present and future generations" (7).

In 2019, the interdisciplinary expert group "EAT-Lancet Commission on Food, Planet, Health" described a nutritional strategy that shows the extent to which the agricultural and food system needs to be changed in order to ensure that everyone has access to a healthy and sustainable diet (3). The commission has integrated several global scientific targets for sustainable food systems, called planetary boundaries. The Planetary Health Diet would make it possible to provide a healthy diet for an anticipated world population of nearly 10 billion people by 2050 while still staying within the planetary boundaries. According to the specifications of the Planetary Health Diet, the focus is on a predominantly plant-based diet that is rich in vegetables, fruit, legumes, whole grains, nuts, and seeds. However, small amounts of animal products are also tolerated. According to the commission, substantial dietary shifts will be required, such as a greater than 50 percent reduction in global consumption of unhealthy foods (e.g., red meat and sugar) and a greater than 100 percent increase in the consumption of healthy foods (e.g., nuts, fruits, vegetables and legumes) (3). In addition, a 50 percent reduction in food loss and waste will be needed.

Baseline assumptions for the calculations of the Planetary Health Diet are an average individual energy requirement of 2,500 kcal per day (10.5 MJ per day) and an adequate protein intake of 0.8 grams per kilogram body weight (3). However, the general energy and macronutrient intake recommendations of athletes are higher than in the general population (8), and it is questionable whether athletes can follow the guidelines of the Planetary Health Diet and meet their individual requirements. A previous analysis showed that on low to moderate training days, athletes would be able to meet their individual energy and macronutrient requirements when following the guidelines of the Planetary Health Diet (9). However, on high and very high training days, adaptations of the Planetary Health Diet have to be performed to meet increased energy and carbohydrate requirements. In this case, the diet should be adapted to include energy- and carbohydrate-rich foods that conserve natural resources. Since energy and macronutrient requirements are not static across the training season and highly depend on training load (10), it might be possible for athletes to follow 100 percent the principles of the Planetary Health Diet on some (resting) days, whereas, on others, adaptations of the diet have to be done to meet increased requirements. According to the principle of "every step counts", it would be important to come as close as possible to the principles of the Planetary Health Diet to contribute to greater sustainability in sport.

It must be highlighted – and this needs to be emphasized during nutrition education for athletes and coaches – that sustainable sports nutrition needs not be superior regarding health and performance outcomes compared to general sports nutrition. If an environmentally sustainable diet equally promotes training adaptation, exercise performance, and health compared to common sports nutrition, it would be irresponsible to further stick to the common, less sustainable sports diet.

In 2020, the Scientific Advisory Board on Agricultural Policy, Food and Consumer Health Protection at the German Federal Ministry of Food and Agriculture defined policies for a more sustainable diet in its Expert Opinion and included a

Table 1

Overview of the goals for a more sustainable diet and their individual effects on the (competitive) athlete. Modified according to Reguant-Closa et al. 2020 (17).

GOALS	POSITIVE EFFECTS FOR THE (COMPETITIVE) ATHLETE
Adjustment of energy and carbohydrate and fat intake to the recommendations according to training loads	- lower intake of cholesterol, saturated fatty acids, and carcinogenic ingredients
	- support in weight management
	- energy and carbohydrate intake is (finally) sufficient to meet individual requirements
Reduction of protein intake to the recommended level	- lower risk of not meeting carbohydrate recommendations due to high satiety caused by protein-rich foods
Replacement of some animal protein with plant protein (protein flip approach)	- getting to know alternative plant-based dishes ("broadening culinary horizons")
	- possibly higher intake of plant-based foods → higher micronutrient and fiber intake
Prioritization of milk, eggs, poultry, and pork over ruminant meat and cheese (within the animal protein fraction)	
Use of fresh, seasonal, regional, and unprocessed foods	- higher micronutrient intake when cooking with fresh ingredients
Limited intake of frozen and canned products and reconsideration of protein powders that result in protein surplus	- lower intake of added sugar, salt, and artificial additives
	- lower risk of exposure to doping-relevant contaminants
	- risk of overdose and interactions is reduced
Education in environmental issues of food choices when creating plates	- training skills to buy, prepare, and store food ("food literacy")
	- meal prepping means that healthy and sport-friendly meals can fit into a busy schedule, and the food is immediately ready after training
	- precise meal planning saves money and time on shopping
Consideration of individual and cultural preferences	

comprehensive view of sustainable nutrition (11). Since many foods have a social, environmental, climate, and animal welfare footprint, a more sustainable diet was defined as a diet that integrates all four target dimensions: health, social, environmental (including climate), and animal welfare (11).

Very recently, the German Nutrition Society published revised food recommendations, where public and individual health and sustainability aspects were equally weighed following mathematical modeling (12). As these national food intake recommendations are the basis for health and performance promoting sports nutrition (13), sustainable food choices might be easier to be implemented by athletes, community catering at German sports institutions and into nutritional education of athletes now.

Ecological Footprints of Typical Athletes' Diets

Franca et al. (2022) examined the environmental impact of food consumption in 91 adolescent athletes (14). The carbon and water footprint were calculated as sustainability indicators and protein food groups were compared to those in the EAT-Lancet reference diet. The authors found that the carbon footprint of most athletes is highly above the critical benchmark for a diet compatible with global warming below 1.5°C, with male athletes showing the greatest environmental impact. This might be explained by the fact that more than one-third of the athletes consumed protein above the recommendation (>2.0 g per kg per day), and animal protein consumption was almost four times higher than that of plant-based proteins. In fact, 85.9 percent of the carbon footprint and 78.4 percent of the water footprint were caused by the consumption of animal protein. In comparison with the EAT-Lancet reference diet, the ingestion of legumes and seeds was below the recommended levels, whereas red meat, dairy, and poultry intake was above recommendations. Furthermore, the authors observed that daily protein intake met the intake recommendations even in athletes with the lowest carbon footprint. Therefore, they concluded that a diet with lower environmental impact can meet protein recommendations in adolescent athletes.

In a study by Carey et al. (2023), more than four hundred competitive athletes and non-competitive active subjects completed an online questionnaire to assess their nutritional practice, perceived nutritional priorities, and preferences for product characteristics (15). The participants had to rate the importance of product features and scientific proof of nutrition product choice, among other questions. "Nutritional profile" was rated as the most important product feature, followed by "taste" and "ease of access". "Sustainability" was rated as least important. However, females rated sustainability aspects higher than males, whereas "level of competition" and "hours of activity per week" had no effect on sustainability ratings.

Seven-day weighed food records were conducted in nine female and male recreational CrossFit athletes with a high Physical Activity Level (2.1) to receive information about their protein sources, food intake, and carbon footprint (16). In addition, interviews were performed to assess further details about their food choice, such as their attitudes towards food, performance, and climate considerations. Finally, their knowledge regarding the climate impact of food was questioned. Total protein intake was very high (2.2 g per kg per day), with a high percentage (70 percent) of animal-based protein sources and a substantial amount of whey protein powder supplementation. This resulted in a high carbon footprint, which was, in the mean, higher than in the average general population. Food intake is primarily aimed at maintaining and improving athletic performance. Further, knowledge of the climate impact of foods varied. However, athletes were open to using more plant-based protein sources, choosing affordable organic products, and being aware of food waste.

The environmental impact of the Athlete's Plate, a nutrition education tool developed to teach athletes how to design their plates depending on training load, was examined in a study by Reguant-Closa et al. 2020 (17). More than two hundred plates for different sexes, meals, and train loads were analyzed using life cycle assessments for the food items. The authors found that in comparison with the general population, the Athlete's ›

Table 2

Cooked amounts of plant and animal-based foods delivering 20 g of protein. Modified according to Meyer & Reguant-Closa 2017 (24). Combining protein-rich, plant-based foods will be the best strategy in obtaining all amino acids if partially or fully replacing animal-based foods.

FOOD	WEIGHT (G)	ENERGY CONTENT (KCAL)	LIMITING AMINO ACIDS (AA)	LEUCINE (G)
PLANT-BASED PROTEIN SOURCES				
Hemp Seeds	57	160	Lysine	0.70
Peanut Butter	68	470	Methionine, cysteine	3.90
Pumpkin Seeds	132	433	Complete plant protein	3.00
Soybeans	204	268	Complete plant protein	2.30
Almonds	227	575	Methionine, cysteine	2.10
Lentils	250	253	Sulfur containing AA	1.30
Chickpeas	284	336	Sulfur containing AA	1.00
Tofu	284	189	Complete plant protein	1.30
Black Beans	295	295	Sulfur containing AA	1.30
Tempeh	306	265	Complete plant protein	2.40
Edamame	318	265	Complete plant protein	1.20
Seitan	408	270	Complete plant protein	no data
Spelt	411	445	No data	no data
Amaranth	500	552	Complete plant protein	no data
Quinoa	567	555	Complete plant protein	0.50
Millet	748	683	Lysine, threonine	0.80
Buckwheat	755	516	Complete plant protein	0.40
ANIMAL-BASED PROTEIN SOURCES				
Beef 15% Fat	73	157	Complete protein	1.70
Pork	73	152	Complete protein	1.90
Chicken	91	100	Complete protein	3.30
Fish (Tuna)	141	179	Complete protein	3.20
Eggs	188	291	Complete protein	2.00
Milk 2% Fat	567	284	Complete protein	0.80

Plate had a higher environmental impact, especially for hard training days with associated increased intake recommendations regarding the amount of food. Furthermore, high animal protein intake recommendations increased environmental impact, as meats such as beef and chicken were the main contributors to the global warming potential of the plate. The authors recommend to reduce animal protein intake and increase in plant-forward and plant-based strategies.

Benefits and Challenges of Sustainable Diets in Athletes

Health Aspects

A plant-based diet is associated with several positive health effects in the general population, e.g., a reduced risk of developing chronic diseases (see further details in the review of Lynch et al. 2018 (18)). This can be explained by the fact that the intake of saturated fatty acids is generally lower, and fiber intake is increased in subjects following a plant-based diet (19). Athletes might also benefit from following a plant-based diet since several studies show that carbohydrate intake is higher in athletes following a plant-based diet and, therefore, can support athletes in meeting (finally) carbohydrate intake recommendations (20, 21). The higher fiber intake, which is usually associated with following a plant-based diet (19), can have potentially beneficial properties on gut microbiome composition. As the constellation and variety of the gut microbiome significantly affect mechanisms like intestinal inflammation, production of short chain fatty acids, fat oxidation, carbohydrate and protein fermentation processes, and protein anabolism, it is assumed that plant-based diets can have positive effects on health and performance in the long-term (21).

However, following a plant-based diet might also increase the risk for low energy availability and the syndrome Relative Energy Deficiency in Sports (RED-S), as consumption of food with lower energy density (such as fruits and vegetables) might reduce total energy intake. Low energy availability and RED-S are associated with several health and performance impairments (22). On the other side, following a plant-based diet can support athletes in weight management, which is of particular importance in weight-sensitive sports.

In subjects following a plant-based diet, intake of plant-based proteins is increased, whereas intake of animal-based proteins is decreased (8). However, an adequate supply of essential amino acids is required for the production of proteins such as immunoglobulins, cytokines, and acute-phase proteins and, therefore, is important for immune defense (23). Vegan athletes should increase total protein intake and combine different protein sources to increase the bioavailability of protein sources (18).

However, most sports nutrition experts, as well as the EAT-Lancet Commission, clearly point out that a vegan diet is not necessarily required when trying to eat sustainably (3, 6, 24). Instead, a protein flip approach is recommended, where 1/3 of accustomed protein intakes should be reduced, 1/3 of animal-sourced protein should be replaced by plant-based protein, and the remaining 1/3 of protein may be supplied by medium GhG emitting meat such as poultry or grass-fed beef (24). The necessity of the protein flip approach in athletes' diets becomes clear when considering the fact that meat ingestion accounts for more than 50 percent of the protein intake in the general population. If a 60 kg athlete with a protein requirement of 90 g per day followed the typical western diet pattern, this would be translated into a daily cooked meat intake of 172 g. The same protein intake pattern in an 80 kg athlete (protein requirement of 120 g/d) would result in a cooked meat intake of 230 g/d (24), which is very close to the recommended maximum intake of meat per week (12).

Due to the lower bioavailability of plant-based iron sources, a higher prevalence of decreased iron status is frequently observed in vegans and vegetarians, leading to insufficient hemoglobin synthesis, which can negatively affect health and endurance performance (25). Vitamin D intake might also be lower in subjects following plant-based diets (19); however, it can possibly be compensated by endogenous synthesis or supplementation (26). Lastly, vitamin B12 intake is insufficient in subjects following a strict vegan diet and has to be supplemented. However, due to higher intake of fruits and vegetables, antioxidant intake might be increased in subjects following a plant-based diet.

Upper respiratory tract infections are common in elite athletes (27). However, absence from training is incompatible with success in elite sports, which demands a consistently high training volume (23). High intake of antioxidants (e.g., vitamins C and E) may be particularly important during heavy exertion

or infection when oxidative stress increases to neutralize reactive oxygen and nitrogen species (23). Some other micronutrients (e.g., iron, zinc and magnesium) play important roles in nucleotide and nucleic acid synthesis and can limit tissue damage (23). An energy-balanced plant-based diet with an intake of a wide variety of fruits and vegetables might increase immune defense and reduce the risk of upper respiratory tract infections. However, no study has been available assessing the relationship between diet (e.g., vegan/vegetarian vs. omnivorous) and the prevalence of upper respiratory tract infections in athletes.

To conclude, an appropriately planned and balanced plant-based diet can meet recommended energy, macronutrient, and micronutrient intakes. However, supplementation of vitamin B12 is necessary when following a strict vegan diet. Iron and vitamin D are also "critical" nutrients, and supplementation has to be considered.

Performance Aspects

There is currently no study available assessing the effects of a "sustainable" diet on exercise performance. However, several studies investigated the effect of plant-based (vegetarian or vegan) diets on physical performance and will be summarized in the following chapter.

The properties of plant-based diets may impact cardiac output, hemoglobin concentration, mitochondrial function, and pH-buffering capacity, all factors that might affect endurance performance (21). The decreased iron stores, which are frequently observed in vegan and vegetarian athletes, can impair hemoglobin synthesis and concomitant endurance performance (25). However, in most of the studies, vegetarian athletes had significantly higher carbohydrate intakes than omnivorous athletes, increasing substrate availability during intense endurance exercise, which is potentially advantageous for endurance performance (20, 21). Lower protein and creatine intakes were detected in vegan and vegetarian athletes than in omnivorous athletes (20, 28). As muscle protein synthesis depends on creatine and protein availability, the macro- and micronutrient composition of plant-based diets may elicit potentially disadvantageous properties for strength performance (21).

In several reviews, the effect of plant-based diets on exercise performance was examined (20, 21, 29, 30). In most of these reviews, no distinguished differences in physical performance between plant-based and omnivorous diets were identified, concluding that a plant-based diet does neither improve nor hinder athletic performance. Only in the review of Damasceno et al. (2024), moderate but positive effects of plant-based diets on aerobic performance, and no effects on strength/power performance were found (30). However, substantial variability among the experimental designs, aims, and outcomes requires further research, especially in elite athletes.

Educational Aspects

As pointed out, sustainable sports diets need not be superior regarding performance outcomes compared to typical sports nutrition concepts – athletes need to be educated that it is well enough if a sustainable sports diet equally supports training adaptation and equally promotes exercise performance. Thus, athletes and their supporting teams need to be educated and supported to make prudent and sustainable food choices, starting from grocery shopping, packaging, food waste and packaging waste reduction, preparation techniques, meal preparation, food storage, and fueling while traveling.

Table 3

Overview of green house gas emissions (GhG) of different foods (modified from (24)). *=may be as high as 20-50 kg CO_{2eq}/kg edible weight.

LOW GHGS <1 KG CO_{2EQ}/KG EDIBLE WEIGHT	MEDIUM GHGS 1-4 KG CO_{2EQ}/KG EDIBLE WEIGHT	HIGH GHGS <4 KG CO_{2EQ}/KG EDIBLE WEIGHT
Potatoes	Milk, Butter, Yogurt	Beef*
Pasta	Chicken	Lamb*
Bread	Eggs	Pork
Oats And Other Grains	Rice	Fish
Vegetables (e.g. Onions, Peas, Carrots)	Breakfast Cereals	Cheese
Fruits (e.g. Apples, Pears, Plums)	Nuts And Sees	
Beans, Lentils	Biscuits, Cakes, Dessert	
Confectionary	Fruits (e.g. Berries, Banana, Melons)	
	Vegetables (e.g. Salad, Mushrooms, Green Beans, Cauliflower, Broccoli)	

Environmental Aspects

The increase in animal food consumption and the world's demographic explosion render the current food system unsustainable, and a dietary shift towards a plant-based diet is an inevitable strategy (31). Reducing or avoiding animal-sourced food, particularly meat, decreases the environmental impacts of the food system (6). An analysis of agricultural production data revealed that producing one kg of edible protein from kidney beans requires approximately eighteen times less land, ten times less water, nine times less fuel, twelve times less fertilizer, and ten times less pesticide than producing one kg of protein from beef (32). The authors concluded that the substitution of beef with beans would significantly reduce the environmental footprint. However, it is not necessary to completely avoid the intake of animal-sourced food, because flexitarian diets with lower intake of animal-sourced food can significantly reduce environmental impact (6). This could be useful for athletes, as it allows them to meet their protein needs without exceeding them.

When comparing different food products, it is important to consider nutrient composition and quality. For example, the environmental impact of plant-based meat alternatives is lower than that of meat (32). However, if the nutritional quality (e.g., the amino acid profile of protein, protein digestibility, and micronutrients) in meat is taken into consideration, the differences are smaller but remain significant (6). Therefore, when evaluating the environmental impact of the athletes' diet, it will be crucial to consider protein quantity, quality, and distribution relative to exercise.

Approaches and Ways Towards Sustainable Sports Nutrition

According to Sabaté & Soret (2014), extreme downward shifts in meat and dairy consumption by large segments of the world population and concomitant shift to plant-based diets are perhaps the most rational and moral path for a sustainable future for the human race (31). Reguant-Closa et al. 2020 (17) developed environmental priority areas ("hotspots") to promote environmental sustainability in athletes: (1) adjust energy, car- ›

bohydrate, and fat intake to the recommendations according to training loads, (2) reduce protein intake to the recommended level, (3) replace some animal protein with plant protein (protein flip approach), (4) within the animal protein fraction, prioritize milk, eggs, poultry and pork over ruminant meat and cheese, (5) use fresh, seasonal, regional, unprocessed foods and (6) limit frozen and canned products and reconsider protein powders that result in protein surplus, (7) obtain education in environmental issues of food choices when creating plates, and (8) consider individual and cultural preferences. In table 1, an overview about the goals for a more sustainable diet and their individual effects on athletes is shown.

In the literature, alternative protein sources such as insects, plants, or mycoproteins and new technologies to upgrade by-products (e.g., protein hydrolysis) are discussed as adding high value regarding bioactivity and sustainability aspects (20). However, according to the "Protein Flip Initiative" (21), it is simply possible to substitute animal-based protein sources with plant-based protein (table 2) and reducing carbon footprint of food (table 3).

Besides the aforementioned changes in diet composition, which are necessary to achieve a more sustainable dietary behavior, it is also necessary to reduce food waste. The avoidance of food waste could reduce the environmental impact of food by 30-40 percent (21), and was also a relevant assumption for calculations of the Planetary Health Diet, where food waste has to be reduced by 50 percent (1). For athletes, food waste could be significant due to the lack of time and skills in food handling and storage and frequent traveling (6). Increasing the food literacy of athletes can probably reduce food waste, as knowledge about the storage and preparation of food will be enhanced.

Athletes should also choose seasonal, local and fresh foods to lower environmental impact of their diet. Since athletes often eat in dining halls of institutions or training centers, when planning the menus, fresh seasonal fruits and vegetables should be favored, as packaged, processed, frozen, or canned foods not only elevate the environmental impacts but also may compromise flavor and nutrition (6).

Several tools, such as the Vegetarian/Vegan Athlete's Plate® (33), the VegPlate for Sports, a vegetarian food guide (34), and the Planetary Health Diet for Athletes Tool (9) have been developed to support athletes in choosing nutritious plant-forward meals. Results from a pilot study showed promising results regarding the applicability of the Vegetarian/Vegan Athlete's Plate®, as college-aged athletes improved their understanding of a vegan and vegetarian diet for athletes, and the majority of athletes rated the tool as "useful" (33). However, these tools still have to be evaluated to be used in elite athletes for a longer time period.

Conlusion

Athletes significantly contribute to greenhouse gas emissions, particularly through high energy consumption, traveling, and the ecological footprint of common athletic diets, which were shown to often exceed protein intake recommendations. Sustainable dietary changes, such as reducing the consumption of animal-sourced food, avoiding food waste, and meeting but not exceeding protein requirements, can significantly lower the ecological footprint of athletes' diets. Athletes may, as role models, influence public behavior towards more sustainable nutrition practices. Approaches to combine sustainable nutrition with key factors of sports nutrition regarding energy and nutrient intake could support the health and performance of athletes. However, it might be challenging for athletes with poor food literacy and nutritional support by performance nutrition experts, sporting institutions, and the team staff (whole institution approach) might be needed.

Conflict of Interest
All authors have completed the ICMJE Uniform Disclosure Form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organization for the submitted work; no financial relationships with organizations that may have an interest in the submitted work in the past three years; no other relationships or activities that may have influenced the submitted work.

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Summary Box

Due to the often higher ecological footprint of competitive athletes compared to the general population combined with athletic role model function, athletes do have a responsibility to show activism towards a sustainable lifestyle. As nutrition is a major contributor to greenhouse gas emissions, land and water use, changing the individual diet into more sustainable diet is recommended.

Approaches that ensure a healthy, sustainable yet performance-supporting diet include reducing animal-sourced protein, meeting but not exceeding protein recommendations for athletes, protein flip techniques, preferring local food, and avoiding food and packaging waste.

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